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TECHNOLOGY AND FINANCIAL STRUCTURE: ARE INNOVATIVE FIRMS DIFFERENT?

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Abstract

We use data on publicly traded U.K. firms to investigate whether financing choices differ systematically with R&D intensity. As well as looking at a balance sheet measure of the debt/assets ratio, we also consider the probability of raising finance by issuing new equity, and the shares of bank debt and secured debt in total debt. We find a nonlinear relationship with the debt/assets ratio: firms that report positive but low R&D use more debt finance than firms that report no R&D, but the use of debt finance falls with R&D intensity among those firms that report R&D. We find a simpler relationship with the probability of issuing new equity: Firms that report R&D are more likely to raise funds by issuing shares than firms that report no R&D, and this probability increases with R&D intensity. The shares of bank debt and secured debt in total debt are both lower for firms that report R&D compared to those that do not, and tend to fall as R&D intensity rises. We discuss possible explanations for these patterns. (JEL: G32, O31, D21)

1. Introduction

This short paper explores U.K. firm-level data to shed further light on whether more innovative firms make different financing choices, compared to less innovative firms. We do not attempt to provide a definitive answer or explanation here, but report patterns suggesting that further research on this subject is likely to be fruitful. This note forms part of a wider program of theoretical and empirical research investigating ways in which more innovative firms are distinctive in various aspects of their organization.¹

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1. See, for example, Acemoglu, Aghion, and Zilibotti (2003) and Acemoglu et al. (2003).

Theories of capital structure or financial behavior tend not to focus directly on technological characteristics, but suggest reasons why more innovative firms may favor particular sources of finance.

One approach emphasizes bankruptcy costs.² These are likely to be relatively low for firms with a high proportion of tangible capital among their assets, particularly property, and equipment associated with generally applicable technologies. They are likely to be higher for innovative firms with a higher proportion of intangible assets, such as knowledge and reputation, and with more specialized equipment. For a given level of debt, the risk of bankruptcy may also be higher. Both factors suggest that more innovative firms are likely to be less reliant on debt finance, to minimize expected bankruptcy costs.

Another approach emphasizes agency costs and informational asymmetries between investors and firms' managers or entrepreneurs. Thus, Myers and Majluf (1984) point to dilution costs of issuing outside equity when managers are better informed than outside investors about the firm's financial prospects. More specifically, by selling equity to outside investors, the firm's current owners may signal that its future prospects are less than excellent, otherwise they would have chosen instead to remain the full residual claimant on the firm's revenues (e.g., by issuing debt, rather than equity). This signalling problem leads to new share issues being underpriced, which imposes a dilution cost on the firm's initial owners.

Now, it is likely that for more innovative firms there will be a greater degree of asymmetric information between insiders and outsiders, and hence these dilution costs will tend to be higher. If so, new equity will be a particularly expensive source of finance for these firms. On the other hand, more innovative firms are also likely to generate more attractive investment opportunities than less innovative firms. If so, they are also likely to be more reliant on external finance from either debt or new equity than less innovative firms, who are more likely to have sufficient internal funds to finance all their desired investment expenditures. Myers and Majluf's "pecking order" theory of capital structure thus suggests that more innovative firms are likely to be more reliant on external sources of funds, but are likely to favor debt over new equity among external sources, to avoid these relatively high dilution costs.

A third approach emphasizes control rights.³ Here the idea is that the lower the amount of tangible wealth or assets inside a firm, the more outside investors will insist on having control rights over the firm's decisions in order to satisfy their *ex ante* participation constraint. Firms will certainly try first to fund investment from their retained earnings in order to relax the participation constraint of outside investors; but then, as more investment funds are required,

2. See Brealey and Myers (2003), Chapter 18.

3. See Aghion and Bolton (1992) and Hart (1995).

firms will use debt-financing (whereby managers retain control except when the firm defaults on its repayment obligations); and it is only when the project's size (or scope) becomes sufficiently large and/or when assets becomes sufficiently intangible that firms will allocate fuller control rights to outside investors by issuing new equity. To the extent that more innovative firms have more attractive investment opportunities and less tangible assets, this approach predicts that they will tend to be more reliant on new equity finance. This alternative theory of the pecking order thus also predicts that more innovative firms are likely to be more reliant on external funds, but suggests that they may favour new equity rather than debt among these external sources.

In this paper we present evidence on R&D intensity and financial structure from a panel of U.K. listed companies over the period 1990–2002, which we then compare with the predictions of these theories. Our empirical analysis first considers a balance sheet measure of the importance of debt in the firm's capital structure. It then investigates the probability that the firm raises funds by issuing new equity, and the composition of the firm's total debt.

There exists already a substantial empirical literature on the financing of R&D activities.⁴ While many papers in this literature focus on financing constraints as a source of underinvestment in R&D, we are interested here in the nature of more general financial choices made by high-tech or innovative firms. Kaplan and Strömberg (2000) provide interesting evidence on the nature of financial contracts in high-tech firms, suggesting that venture capital contracts are consistent with the predictions of the control rights theory.⁵ Carlin and Mayer (1999) also point to regularities in the relationship between a firm's financing mode and its type of productive activities. The empirical literature on capital structure often includes information on R&D activities as control variables,⁶ without focusing on the financial behavior of innovative firms, and there is relatively little empirical evidence from outside the United States.

The rest of this short paper is organized as follows. Section 2 describes our data and presents our main empirical results. Section 3 summarizes the findings, relates them to the theoretical approaches outlined in this introduction, and finally discusses possible extensions of the work.

2. R&D Intensity and Financial Structure

We use data from published accounts for an unbalanced panel of 900 companies whose shares are listed on the London Stock Exchange, over the period

4. Hall (2002) provides an excellent survey.

5. See also Lerner (1992, 1995) on venture capital financing.

6. See, for example, Titman and Wessels (1988) and Bradley, Jarrell, and Kim (1984).

TABLE 1. Share of firms/observations with positive R&D

	Fraction with positive R&D
Firms	43.6%
Observations	38.1%

1990–2002. The information in their consolidated accounts relates to their worldwide activities, and not only to their operations in the United Kingdom. Our sample includes firms whose main activity is in manufacturing, extraction or construction, but excludes firms whose main activity is in the service sector, including finance. Further details of the sample and the variables we use are provided in the Appendix.

Reporting of R&D expenditure became compulsory for large and medium-sized U.K. firms in 1989, which is why we focus on data from 1990 onwards. Not all firms in our sample are larger than the size threshold at which R&D reporting becomes compulsory, but we have checked that all the results we present here are robust to the exclusion of the smaller listed companies from our sample. The accounting definition of R&D expenditure follows closely the OECD Frascati Manual classification, and there were no tax reasons for reported R&D expenditures to be exaggerated in the United Kingdom over this period.

Table 1 shows that 43% of our sample firms report positive R&D expenditure in at least one year, and positive R&D is observed in 38% of our 6,501 firm-year observations. Among those observations with positive R&D, the distribution of R&D intensity (R&D/sales) is highly skewed, as shown in Table 2. Not only is the mean of 3.09% considerably higher than the median of 1.34%, it is even marginally higher than the upper quartile.

2.1. *The Debt/Assets Ratio*

Table 3 presents regression results for models of the ratio of total debt to total assets. Both debt and assets variables are book values reported on company balance sheets. Total debt includes liabilities with a maturity of less than one year, as well as longer term liabilities, but excludes trade credits and debits. Total assets includes current assets, as well as tangible and intangible fixed assets.

Column 1 reports a basic specification in which the explanatory variables are a zero/one dummy that identifies observations on firms that ever report positive R&D expenditure, and the firm's R&D intensity. Year dummies are

TABLE 2. Distribution of R&D intensity (observations with positive R&D)

Mean	Std deviation	Median	Lower quartile	Upper quartile
3.09%	7.44%	1.34%	0.54%	3.03%

TABLE 3. Total debt as a share of total assets

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable			Total debt/total assets			
Time effects	Year	Year	Year	Year	Year	Year
Group effects	—	—	Industry dummies	Industry dummies	Firm fixed effects	Firm fixed effects
R&D firm dummy	0.023 (0.003)***	0.023 (0.004)***	0.032 (0.004)***	0.030 (0.004)***		
R&D/sales	−0.228 (0.043)***	−0.384 (0.075)***	−0.170 (0.041)***	−0.315 (0.079)***	−0.245 (0.110)**	−0.302 (0.146)**
Employees (millions)		0.710 (0.129)***		0.519 (0.123)***		0.103 (0.320)
Real sales growth		−0.004 (0.008)		−0.011 (0.008)		−0.010 (0.006)*
Profitability		−0.003 (0.001)***		−0.003 (0.001)***		−0.001 (0.000)***
Constant	0.179 (0.006)***	0.173 (0.006)***	0.177 (0.006)***	0.174 (0.006)***	0.171 (0.004)***	0.173 (0.005)***
Observations	6501	5888	6501	5888	6501	5888
R-squared	0.02	0.03	0.06	0.08	0.04	0.04

Notes: Robust standard errors in parentheses.

* Significant at 10%; ** significant at 5%; *** significant at 1%.

R-squared statistics in columns (5) and (6) exclude variation explained by firm fixed effects.

included, as in all reported models, to control for common trends or business cycle effects. We find a significant positive coefficient on the R&D firm dummy,⁷ and a significant negative coefficient on the R&D intensity variable.

This pattern indicates a nonlinear relationship between the debt/assets ratio and the firm's R&D profile. Firms with both high R&D intensity, and those with zero R&D, tend to use less debt finance than firms with positive but less intensive R&D activity. The overall effect of R&D spending on gearing becomes negative when R&D reaches around 10% of sales, which occurs for around 5% of the R&D performing firms in our sample. Most of these firms are in pharmaceuticals, instrument engineering, or telecommunication equipment.

Column 2 shows that this pattern is robust to the inclusion of additional control variables. We find a significant positive effect of firm size on gearing, and a significant negative effect of profitability, but these factors are not highly collinear with our R&D variables. Column 3 shows that this pattern is also robust to including a set of 20 sector dummies, and column 4 confirms robustness to both these sets of controls.

Columns 5 and 6 report within groups or “fixed effects” estimates of these specifications, which allow for permanent unobserved heterogeneity across

7. Very similar results were obtained using a dummy variable set to one only for observations where positive R&D is reported. These dummies were too collinear to determine whether capital structure tends to be different for firms or for observations with positive R&D.

firms in their choice of capital structure. In this case we cannot separately identify the effect of our time-invariant “firm reports R&D” dummy variable. Perhaps surprisingly, given that there is relatively little within-firm variation in R&D intensity,⁸ we continue to find a significant negative effect of R&D intensity on the debt/assets ratio. This indicates that, for the same firm, an increase in R&D intensity is associated with a lower debt/assets ratio; the negative coefficient reported in earlier columns is not simply reflecting cross-sectional differences between firms with low and high R&D intensities.

2.2. *New Equity Issues*

The results presented in the previous subsection indicate that reliance on equity finance tends to increase with R&D intensity among firms that report R&D, although also tends to be higher for firms that report no R&D compared to firms with positive but low R&D expenditures.⁹ However these balance sheet measures do not distinguish between finance raised by issuing new equity, and finance from “internal equity” or retained profits.

Information on finance obtained by issuing new shares is available from the flow of funds statement in U.K. company accounts. Around 80% of the firms in this sample report issuing new equity at least once during our sample period.

To explore whether more innovative firms are more likely to use new equity finance, Table 4 reports logit regression models where the dependent variable is one for an observation in which new equity is issued, and zero otherwise.¹⁰ Column 1 indicates that the probability of issuing new equity is higher for firms that report R&D compared to firms that do not report R&D, and tends to increase with R&D intensity among those firms with positive R&D. Column 2 shows that larger, faster growing, and more profitable firms are also more likely to issue new equity, but these control variables do not change our basic results for the R&D variables. Columns 3 and 4 show that these results are robust to the inclusion of industry dummies.

Columns 5 and 6 report conditional or fixed effects logit specifications, which again control for the effect of permanent unobserved heterogeneity across firms in their propensity to issue new equity. Not surprisingly, this eliminates

8. A regression of R&D intensity on year dummies and firm dummies yields an R^2 of 0.95; the within groups regressions in columns 5 and 6 rely on the residual variation to identify the effect of R&D intensity. In contrast, a regression of R&D intensity on year dummies and industry dummies yields an R^2 of only 0.2.

9. We confirmed that models for the book value of equity relative to total assets are essentially a mirror image of those reported in Table 3. They are not the exact mirror image because both trade debits and deferred taxation are excluded from our measure of total debt.

10. Similar results were obtained in specifications where the dependent variable was defined to be one only if the funds raised from the equity issue exceeded 1% of total sales. This was intended to exclude cases where equity was issued in relation to share-based remuneration, rather than to finance significant investment spending.

TABLE 4. Logit regressions of probability that new equity is issued

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable	Positive amount of new equity issued					
Time effects	Year	Year	Year	Year	Year	Year
Group effects	—	—	Industry dummies	Industry dummies	Firm fixed effects	Firm fixed effects
R&D firm dummy	0.511 (0.064)***	0.449 (0.070)***	0.650 (0.071)***	0.526 (0.079)***		
R&D/sales	6.2230 (1.310)***	7.293 (1.585)***	5.166 (1.453)***	7.156 (1.796)***	5.059 (3.433)	17.933 (6.603)***
Employees (millions)		29.726 (4.073)***		28.609 (4.141)***		9.273 (12.379)
Real sales growth		1.112 (0.155)***		1.060 (0.158)***		0.880 (0.207)***
Profitability		0.125 (0.029)***		0.118 (0.029)***		0.157 (0.092)*
Constant	-18.266 (0.117)***	-20.395 (0.126)***	-19.162 (0.264)***	-20.221 (0.295)***		
Observations	5445	4936	5445	4936	3794	3374

Notes: Standard errors in parentheses.

* Significant at 10%; ** significant at 5%; *** significant at 1%.

the significance of firm size, but we continue to find a significant positive effect of R&D intensity. Again this suggests that, for the same firm, an increase in R&D activity is associated with a higher probability of raising finance from new equity.

2.3. The Composition of Debt

U.K. company accounts report a breakdown of total debt between bank and non-bank sources, and between secured and unsecured debt. Columns 1 and 2 of Table 5 report simple regression models of the share of bank debt in total debt, while Columns 3 and 4 of Table 5 report corresponding specifications for the share of unsecured debt in total debt.

These results indicate that firms that report R&D are likely to borrow a smaller proportion of their total debt from banks, and the share of bank debt in total debt tends to fall further as R&D intensity increases. Conversely, the share of unsecured debt tends to be higher for firms that report R&D, and tends to rise further as R&D intensity increases, although the latter result is only weakly significant. We note that these results on R&D intensity are also not robust to the inclusion of firm-specific fixed effects; that is, we cannot rule out the possibility that unobserved characteristics of firms, that happen to be correlated with R&D activities, may be driving the effects of R&D intensity reported in Table 5.

TABLE 5. The composition of debt

	(1)	(2)	(3)	(4)
Dep. variable	Bank debt/total debt		Unsecured debt/total debt	
Time effects	Year	Year	Year	Year
Group effects	Industry	Industry	Industry	Industry
R&D firm dummy	-0.056 (0.011)***	-0.031 (0.011)***	0.191 (0.012)***	0.157 (0.013)***
R&D/sales	-0.576 (0.116)***	-0.526 (0.211)**	0.174 (0.122)	0.302 (0.231)
Employees (millions)		-2.792 (0.359)***		3.294 (0.461)***
Real sales growth		-0.059 (0.019)***		-0.023 (0.023)
Profitability		0.007 (0.003)**		0.000 (0.004)
Constant	0.716 (0.014)***	0.719 (0.015)***	0.591 (0.018)***	0.604 (0.019)***
Observations	5971	5411	6043	5484
R-squared	0.08	0.10	0.08	0.10

Notes: Robust standard errors in parentheses.

* Significant at 10%; ** significant at 5%; *** significant at 1%.

3. Summary and Conclusions

Our results suggest that the financial behavior of more innovative firms, as indicated by the presence and extent of R&D expenditure, differs from the financial behavior of less innovative firms in a number of ways.

In Section 2.1 we found an interesting nonlinear relationship with the use of debt financing, as measured by the ratio of total debt to total assets. Firms with positive R&D tend to use more debt than firms with zero R&D, but among the R&D performing sub-sample the use of debt declines with R&D intensity. Those firms with the highest R&D intensities in our sample tend to have the lowest levels of gearing. In Section 2.2 we found a simpler relationship between R&D behaviour and the probability that firms raise finance by issuing new equity. Firms with positive R&D are more likely to issue equity than firms with zero R&D, and the use of new equity increases further with R&D intensity. Those firms with the highest R&D intensities in our sample thus tend to be the most likely to use new equity finance.

The overall picture that emerges from these two sets of results appears to be largely consistent with the control rights approach, whereby the pecking order between internal finance, debt and outside equity is driven by the interplay between the size of desired investment, the tangibility of assets, the allocation of control rights, and the investors' participation constraint. More specifically, as we move from less innovative firms to consider firms with increasing R&D intensities: First, more innovative firms may have more attractive investment opportunities and thus become more reliant on external sources of finance, but

first prefer for debt as it involves giving up less control rights than new equity; however, more highly innovative firms will have no choice but to issue outside equity in order to meet the investors' participation constraint. This can potentially explain why the probability of issuing new equity rises monotonically with R&D intensity (as we found in Section 2.2), while the use of debt finance starts to decline eventually as R&D intensity increases (as we found in Section 2.1).

Our findings do not fit so well with the dilution costs approach based on informational asymmetries between firms and their outside financiers. On the one hand this approach also predicts that more innovative firms should rely more on external finance (both debt and new equity) than less innovative firms. On the other hand it suggests that the most innovative firms should find new equity finance particularly expensive, which is difficult to reconcile with our finding that among U.K. listed firms, those with the highest R&D intensities are the most likely to issue new equity (Section 2.2).

The extent to which bankruptcy costs may help to account for these patterns remains to be explored more carefully. On the one hand, publicly traded U.K. firms have low bankruptcy rates, so that our sample may not be the best place to look for evidence that bankruptcy costs are a major influence on borrowing behaviour. On the other hand, there is significant variation across listed firms in corporate bond rates, which suggests there may also be significant variation in the perceived risk of bankruptcy. In any case, bankruptcy costs alone cannot explain the finding that, over some range, more innovative firms are more highly leveraged than less innovative firms.

In Section 2.3 we analyzed the relationship between R&D intensity and the composition of debt. The shares of bank debt and secured debt in total debt are both lower for firms that report R&D compared to those that do not, and tend to fall as R&D intensity rises.¹¹ The significance of these patterns is however dominated by cross-sectional differences between firms, and becomes very weak when we control for firm-specific fixed effects and rely on time series variation within the observations on the same firm for identification.

There are several extensions to this line of research that we intend to pursue. One important development will be to use other indicators of the extent of firms' innovative activities than simply their R&D intensity. In this paper, we avoided some of the problems of reliance on R&D intensity by including industry dummies—so that in effect we considered whether the firm's R&D intensity was high relative to a sectoral norm—and by controlling for firm-specific fixed effects—in which case we further control for the firm's normal level of R&D activity. Nevertheless it will be useful to confirm our results using alternative technological indicators. One possibility will be to construct firm-specific mea-

11. Barclay and Smith (1995) report a somewhat related result, namely that firms with "higher growth options," as measured by the ratio between the market value and the book value of the firm's assets, issue more short-term debt.

asures of total factor productivity, relative either to the most productive firms in the U.K. industry or worldwide, along the lines of those used at the industry level by Griffith, Redding, and Van Reenen (2001).

We will also consider a wider range of econometric estimators and specifications. GMM procedures for dynamic panel data models will allow us to control for some forms of measurement error. This approach will also allow us to investigate whether the differences we find are temporary or permanent, in the context of dynamic model specifications, and to address issues of (Granger) causality.

Finally, a limitation of the present study is that we have considered only publicly traded U.K. firms, that are predominantly both large and mature. We hope that future work will be able to investigate these issues using data for smaller or newer companies, where differences between more innovative and less innovative firms may be even more significant.

Appendix

The company accounts data were obtained from Thomson Financial Datastream. Using the GDP deflator (computed from U.K. National Statistics series ABMI and YBHA) we convert all financial variables into constant prices.

Datastream provides a breakdown of firm sales according to U.K. SIC codes. We allocate firms to the industry in which most of their sales occurred. If they have the same sales in two industries, we pick the one with the highest reported profits.

We keep industries if we have information on at least 20 firms. Otherwise we use a higher level of aggregation. If this also fails we drop the industry from our sample. We drop all industries in the service sector. This leaves us with 20 industries: Extraction, construction, and 18 manufacturing sectors, at roughly the two-digit level.

We have kept data cleaning to a minimum, but we do drop observations if:

- total assets are negative, increase by more than 100% or fall by more than 50% in a year;
- total capital employed is negative;
- accounting years are shorter than 11 months or longer than 13 months;
- any variable required for our analysis is missing;
- firms report R&D erratically, that is, switch more than once between reporting zero and nonzero R&D; and
- bank debt or unsecured debt is greater than total debt.

Our dependent variables are defined as follows:¹²

12. Numbers in parentheses refer to Datastream accounts items.

- Total debt/total assets: Stock of debt repayable in more than one year (321) plus stock of debt repayable within one year (309) over total assets (392)
- Indicator for new equity issued: A dummy variable equal to one if cash raised from issue of ordinary equity or preferred stock (429) is positive, and equal to zero otherwise
- Bank debt/total debt: Total bank debt (275 + 387) over total debt (321 + 309)
- Unsecured debt/total debt: Unsecured debt (274) over total debt (321 + 309).

Our R&D variables are defined as follows:

- R&D firm dummy: A dummy variable equal to one if R&D expenditure (119) is reported to be positive in at least one year, and equal to zero otherwise
- R&D intensity: R&D expenditure (119) over total sales (104).

Our control variables are defined as follows:

- Number of employees: Total number of domestic and overseas employees, including part-time, in millions (219)
- Real sales growth: Growth of real sales (104) over the year
- Profitability: Operating profits (137) over capital stock constructed using the perpetual inventory method.

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